

# Flight Software Technology Roadmap

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**Abstract** – Advances in flight software technology are required to meet demands for increasing capability of missions. In addition, advances in software components and engineering technology enable increased capability and operability that flight software systems can offer to missions. The challenge for the Flight Software Branch at GSFC is to stay abreast of promising developments related to flight software technology and engineering that are on and over the horizon and to identify those having greatest potential synergy and return on investment.

To that end, the Flight Software Branch has developed a roadmap that identifies the technologies needed to support NASA missions through 2013, and defines a strategy for selecting those technologies. The initial focus was on five key technologies, namely domain modeling, layered architectures, interface standards, unified simulation environment, and automated tools. All are related to the core onboard data system, which is believed to hold the greatest potential for reducing cost, shortening development time, and supporting re-use and portability.

## 1.0 Introduction

Developments in flight software technology are required to meet demands for increasing capability from missions. The evolution of scientific research goals, of remote sensing technology and of science data processing methods are just a few examples of technologies that place greater demands on spacecraft capabilities that flow down to flight software components.

Simultaneously, advances in software components and engineering technology enable increased capability and operability that flight software systems can offer to missions. Parallel development of the flight hardware that hosts flight software systems is gradually relieving the limitations of memory, processing speed, and communication bandwidth imposed by the perennial constraints of power, weight, volume, and radiation.

The challenge for the Flight Software Branch is to stay abreast of promising developments related to flight software technology and engineering that are on and over the horizon and identify those that have the greatest potential synergy and return on investment. These key technologies must be incorporated into our architectures, products, methods and tools in a way that

increases our capacity to meet the demands of future missions productively and flexibly.

## 1.1 Purpose

The purpose of the Flight Software Roadmap, hereafter referred to as just “the Roadmap,” is to formulate the direction of Flight Software architectures and enhancements needed to support NASA missions in the years 2003 through 2013. The Roadmap can be used to guide future technology development activities and includes an approach for establishing, managing, and maintaining an effective technology development and infusion program.

The technologies discussed in the Roadmap include (1) those technologies that relate to the functional characteristics of the mission, (2) the enabling technologies of the onboard data systems, and (3) the development technologies that make construction of complex software systems cost-effective or even possible. Successful software development also depends on well-defined, institutional methods and tools, which are addressed in the Roadmap, however, the process infrastructure, which is also essential, is not.

## 2 Overview

This section presents an overview of the Roadmap in terms of its intended role in the GSFC’s Flight Software Branch. Some basic principles essential to effective technology development are presented.

## 2.1 Goals for Flight Software Technology Development

The FSW Branch is faced with the challenge of advancing the state-of-the-art and state-of-the-practice of flight system development while simultaneously providing flight software to mission projects efficiently and effectively. In addition, the risk associated with infusion of new products into a mission must be identified, agreed upon, and managed.

The four main flight software technology development goals of the FSW Branch include: 1) establish and maintain a strategic planning process that supports technology evolution; 2) meet customer needs by applying a full range of appropriate technologies to

meet science goals, as well as communicating to the Enterprises the opportunities enabled by advances in software technology; 3) provide high-quality, low-cost products by improving processes, and using automated tools which promotes reuse; and 4) maintain a framework that supports technology advancements and infusion. Framework efforts include maintaining core flight software competencies and expertise, standardizing and implementing the best software engineering practices and development processes, maintaining knowledge of the latest development tools, and maintaining state-of-the art flight-like technology labs where studies and prototyping can be performed.

## 2.2 Guiding Principles

To achieve the four goals listed above, the following guiding principles will be followed:

1) Maintain Balance Between Research, Development and Mission Infusion: Effective research, development and technology insertion are key to providing opportunities for continual advancement of mission goals. However, an appropriate balance between these areas is also critical. Research activities push the edge of technology, providing a view of *potential* solutions, but with unknown risk factors. Development of these technologies in a mission-like environment provides insight into their feasibility and application, thus better defining associated risk. The Flight Software Branch must use both research and development to improve the efficiency and manage the risk of infusing new technologies needed to support mission applications.

2) Maintain Core Competency: Project Goddard specifies core competencies as essential to fulfilling customer expectations. Expertise in flight software is essential for meeting the core competencies of advancing state-of-the-art flight and ground systems and competency in the full suite of engineering skills necessary to lead a full mission system.

3) Accumulate Useable Artifacts: A focus on reusable products, components, document templates, etc., support the goal of technology and cost.

4) Ensure Outside Participation: It is important to promote partnerships with other agencies, universities, and industry in order to apply emerging, innovative technologies and practices within the software engineering field. The GSFC Flight Software Branch must also be a leader in anticipating the future and leading change.

5) Effectively Integrate Processes, Products, Infrastructure and Workforce: Effective technology

insertion requires that all the “machinery” that supports development of mission products be upgraded to incorporate both current and new technology. Training may be required so that personnel other than the original development team can become sufficiently knowledgeable to apply it. Standard products must be upgraded, development and test processes may need to be modified, and any necessary tools must be available and accessible to those who need them.

## 3 STRATEGIC PROCESS

A **strategic process** was applied in the preparation of the Roadmap. The result of applying this process is a set of technology goals in alignment with mission goals. The Roadmap will be used, in conjunction with budget and resource information, to prepare a **development plan** for each nominated technology.

The strategic process identifies needs by reviewing **mission drivers** as a function of time. Next, the mission drivers are reviewed against the current **state-of-practice** within GSFC to reveal the gaps that must be filled and the required timeframes. Then, an approach to filling the gaps is developed. The state-of-practice outside GSFC including relevant work being done at corporations, universities, other government agencies, and standards groups like SOIF and OMG, is researched. A determination of existing methods or products that can be applied or adapted is made with regard to maturity level. Where gaps still exist we must look farther into the future, so state-of-the-art and emerging technologies are investigated.

Finally, taking all the above-mentioned items into consideration, there is a decision process that **nominates specific technology development goals**. That process will take into consideration return on investment, cost/benefit, quality of product, risk, priority, and customer and developer buy-in. An abbreviated pass through the strategic process was performed when developing the Roadmap. In subsequent efforts, additional analysis will leverage this initial foundation to refine the definition of our technology needs

## 4 Flight Software Technology Roadmap

The following paragraphs present the results of applying the strategic process described above. The required flight software technologies were defined and categorized into three areas: Spacecraft Applications, Onboard Data Systems, and Flight Software Development. The categories are not mutually exclusive; rather they are inter-dependent. The initial

results and conclusions of the review of missions are presented as well as timelines for development of identified technology areas. Further discussion and refinement are needed.

#### 4.1 Mission Drivers and Needed Capabilities

The missions that were the most significant in terms of driving the development of new flight software technology are listed in the Roadmap and include the most significant capability needs, the associated enabling flight software application technology, and the approximate timeframe that technology must be sufficiently developed to support that mission, generally about 3 to 4 years prior to launch. Upon examination of the operational capabilities needed to accomplish the listed missions, the principal flight software technology areas that are needed or would contribute to meeting the mission goals were deduced. These technology areas are grouped into three categories: (1) spacecraft applications technology, (2) onboard data system technology, and (3) flight software development technology.

##### 4.1.1 Spacecraft Applications Technology

From a flight software perspective, many of these technology developments will occur as advancements in the applications running within the well-established, robust, and adaptable framework of the onboard command and data handling system (C&DH) shown in Fig. 1. Examples of this include:

- Onboard science data processing
- Science event detection and response
- Event based scheduling approaches
- Flight dynamics associated with constellations and formation flying

##### 4.1.2 Onboard Data System Technologies

Some of the technology areas are intrinsic to the characteristics of the onboard data system itself rather

than the applications running in the C&DH framework. Examples of these are:

- Higher data rates
- New external bus drivers and interfaces
- Space communication protocols
- File management
- High precision time distribution

Also in this category of onboard data system technologies are attributes of the C&DH that provide flexibility and generality resulting in higher reuse of existing software systems and lower cost and development time. It is critically important to create a technical foundation that allows us to build reusable components so we can focus more resources on new development and technology. Examples of these are:

- Standard application interfaces
- Uniform external device interfaces
- Dynamic application loading and installation
- Standard information exchange protocols

This roadmap is shown in Fig.2.

##### 4.1.3 Flight Software Development Technologies

The demand for flexibility and reduced development time and cost points to a third technology area, shown in Fig. 3, involving the processes by which flight software is developed, tested, maintained and modified or reused for subsequent missions. These cannot be considered to be mission drivers, but are essential to effectively meeting mission needs within tightening resource constraints. Examples of items in this area include:

- Formal reuse processes
- Automated tools for development and testing
- Unified simulation environments and testbeds

## ADVANCED AUTONOMY

### Goal-Driven Operation

- Basic goal engine
- Distributed Goal Decomposition
- Sci vs. H&S Arbitration
- Science Data Synthesis

### Event-Based Scheduling

- ASAP sequence execution*
- In-Situ Science Event Response*
- Onboard event-based science planning, scheduling and re-scheduling

### Fault Resolution

- Network Management*
- Network Redundancy Management
- Trend Analysis
- Advanced Fault Detection, Determination, Isolation & Recovery

### S/C Operation

- Event-Driven Slew to Target
- Autonomous Navigation
- Adaptive Scheduler
- Multi-S/C Collaboration

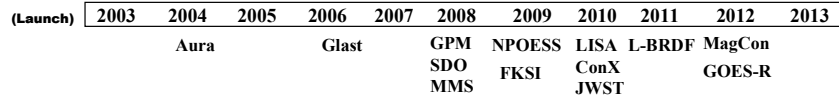


Fig. 1 Spacecraft Applications Technology (1 of 2)

## Optimized Science Data Handling

- Science Feature Extraction:  
Pattern Recognition, Feature Identification,  
Extraction, Analysis, and Reduction

- High Fidelity Science Data Fusion/Compression

- Discrimination & Selection of Science Data:  
Onboard Filtering to reduce downlink,  
Tailored data directly to user

- Constellation Data Sharing, Processing, Analysis

## Constellation Management

- Formation Flying:*
  - Relative Attitude Sensing & Control
  - Med. & High Precision Relative Navigation
  - Collision Avoidance
  - Cooperative Maneuvering

- Sensor Web Support  
- Distributed Data Processing

**FONT KEY**  
 •*Italics* =>Existing or In-devel  
 positioned by completion date  
 •Non-italics =>Technologies for  
 future missions positioned by  
 development start date

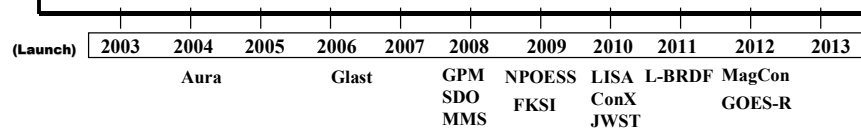


Fig. 1 Spacecraft Applications Technology (2 of 2)

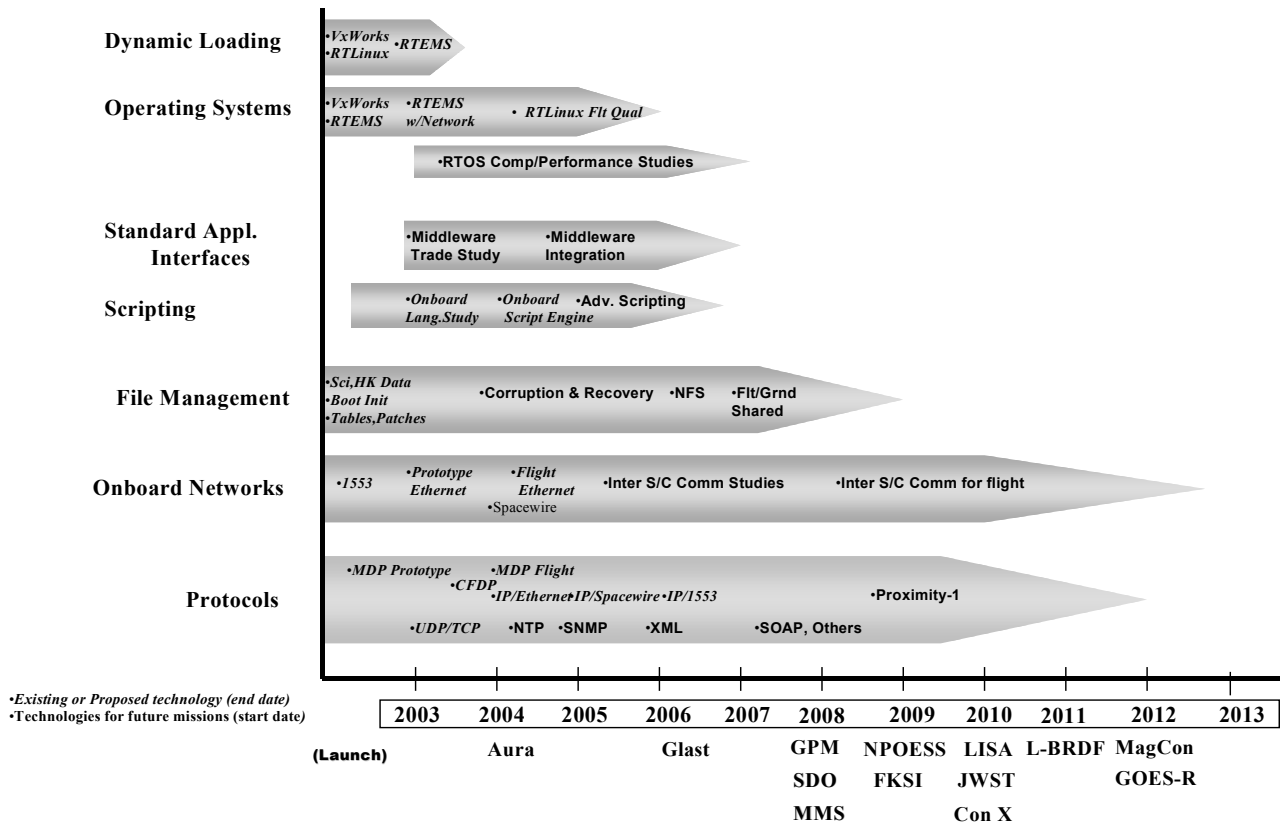


Fig.2 Onboard Data System Technologies

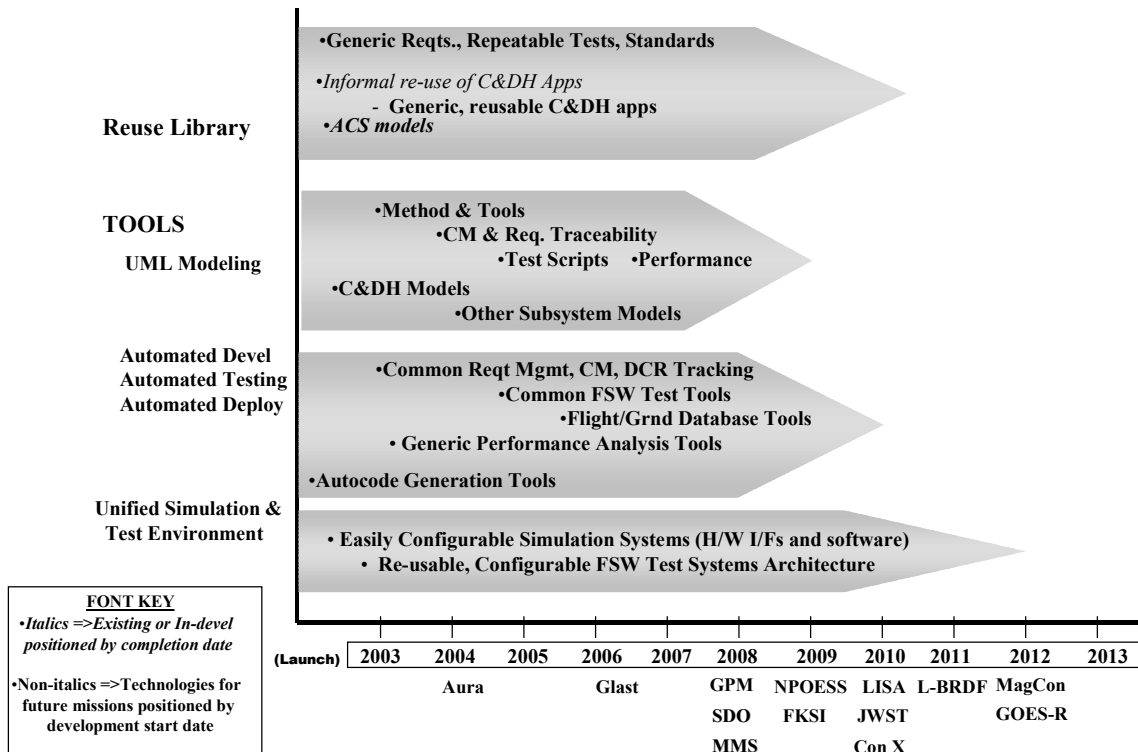


Fig.3 Flight Software Development Technologies